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POWERING AIRPOWER: IS THE AIR FORCE'S ENERGY SECURE?

by

Noah J. Fillian

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Instructor: Dr. Ouellette

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Table of Contents

Disclaimer i
Table of Contents ii
Table of Figures iii
Preface iv
Abstract vi
Section I - Introduction 1
Section II – Background 5
Problem Background and Significance 5
Utility Acquisition 6
Section III – Key Issues and Discussion Points 8
Historical Consumption and Costs 8
State of Infrastructure 10
Future Assumptions 13
Section IV – Potential Solutions 16
Evaluation Criteria for Solutions 16
Reduce Consumption 17
Infrastructure Upgrade/Alterations 19
Alternative Onsite Generation 22
Contracting Avenues 24
Section V – Solution Evaluation and Comparison 27
Section VI – Recommendations 30
Section VII – Conclusion 32
Endnotes 33
Bibliography 36

Table of Figures

Figure 1. Example Solution Matrix 16

Figure 2. Key Microgrid Parameters 22

Figure 3. Solution Matrix...28

Preface

My Air Force engineering career started at Joint Base Langley-Eustis in 2009 where I worked as an electrical engineer, and one of my primary functions was to manage the electrical utility infrastructure. In that role I was mainly concerned with cost and maintenance burden. My only concern with energy security was to consider hurricane level winds when executing the design and repair projects for the system.

In 2014 I started working in energy management at Wright-Patterson Air Force Base. My outlook on the electrical utility system changed. I no longer considered cost and maintenance as the primary factor in utility system design. My vision of an installation's utility system was broadened through not only my new position, but also the Air Command and Staff College curriculum. I now have a better understanding of the long-term implications of energy security vulnerabilities as well as the cost burden the AF has for energy consumption. Installations are still driven to reduce energy consumption from a cost-based perspective, but energy security gets only a minor focus at the installation. The Air Force's lack of attention to the true energy security problem at its installations is what sparked my interest in this topic.

This research paper could not exist without the help of my career colleagues guiding me as an engineer and installation energy manager and my academic peers and instructor conducting thorough critiques of my draft efforts. This constructive feedback and mentoring have proved invaluable for me to produce this final product. My name is on the title sheet of this work, but it was truly a team effort.

On a more personal level, I would not have time to dedicate to this research if it were not for my understanding and supportive wife. Her home and family efforts allowed me to focus when I needed to quietly think, which was quite often this last term. She managed to free up my

own time all while driving her own career, which currently has her traveling the country nearly 50 percent of the time. Without her sacrifice, I would not have succeeded.

Abstract

Energy is consumed at every level of warfare and is required for Air Force (AF) mission success. As adversaries seek more asymmetrical advantages against the United States and global climate change gives rise to more severe weather patterns, the security of AF energy is at an increasing level of risk. Adding to this problem, the infrastructure budget is not growing, making it more difficult to both meet energy-related mandates and improve energy resiliency. This paper evaluates energy security at the installation level and asks the question “How can the Air Force improve energy source and infrastructure weaknesses to sustain future mission requirements?” Energy consumption reduction, infrastructure upgrades, alternative onsite power generation and acquisition methods for these projects are part of this analysis. Focusing primarily on electrical energy, this paper will employ a problem/solution framework and propose a course of action to help set the AF on a path to correct its complex energy security problem. The final recommendation is to implement the right combination of consumption reduction, infrastructure upgrades and, primarily, alternative onsite power generation at AF installations. To achieve this the AF must reconsider how it prioritizes and funds energy-related projects to best meet the AF mission.

Section I - Introduction

Saving energy or generating power is far from the Air Force's primary mission; however, energy is needed to execute every aspect of the Air Force (AF) mission. From an installation standpoint, the AF requires electricity to power maintenance and support facilities, communications systems and other computer-based equipment. It is in the AF's best interest to have a secure, assured supply of energy to maintain core mission success under any circumstances. With US adversaries seeking to leverage any asymmetrical advantage possible, the interconnected power grid is increasingly at risk and with ever-tightening budget constraints, it is becoming more difficult for the AF to address these energy infrastructure concerns.

Improvements in physical security, infrastructure, consumption reduction and renewable energy all add to the security of an installation's electrical energy supply. Updating key parts of the electrical grid will improve reliability and increase its inherent defenses against both severe weather and adversarial attack. Reducing the AF's need for energy reduces its utility budget and frees up more funding for direct mission needs. More on-site renewable energy generation increases AF readiness in crisis times by minimizing the AF's dependency on fossil fuels.

Financing these improvements is a significant concern. Current facility project funding guidelines require energy related projects to fully payback financially either within a predetermined term or, at maximum, the lifecycle of the equipment installed. Some required infrastructure upgrades do not provide any energy cost savings back to the AF. Further, reliable onsite power generation from renewable resources is the ultimate solution to installation energy security. These avenues have a higher cost than conventional power delivery and, therefore, will not have an acceptable payback period from a funding perspective.

This research aims to find how the AF can improve energy source and infrastructure weaknesses to sustain future mission requirements. Though AF installations use a variety of energy commodities including electricity, natural gas, fuel oil and water, this research is focused on electrical facility energy.

How can the AF improve energy infrastructure weaknesses to sustain future mission requirements? The AF needs to strengthen its energy infrastructure by upgrading physical security, increasing onsite renewable power generation and reducing overall energy consumption. Modifying project funding parameters and focusing more resources on holistic energy security projects rather than focusing funds on energy cost savings projects will help the AF achieve these goals.

Success in air, space and cyberspace requires energy, and the current AF model of energy security is insufficient because the AF does not consume energy from long-term sustainable sources. Further, power is generated at distant locations and transmitted to installations through an interconnected utility grid physically exposed to weather and potential adversary attack. Though the AF has made some progress towards energy intensity reduction, increased mission requirements have stagnated bottom line consumption for the Service; this lack of reduced consumption compounds all other issues highlighted above.

Without secure energy sources and delivery methods, the AF cannot meet future mission requirements. Vulnerabilities in the electrical grid make an easy target for terrorists or other actors to negatively impact the AF. Backup power capabilities at AF installations rely on diesel generation. Diesel fuel must be delivered to the installation adding yet another energy related vulnerability in achieving the mission at the installation level.

The entire world is grasping for the same natural resources that superpower nations control. The US lags behind China in total energy production, just barely edging past the Middle East and Russia.[1] Smaller developing nations with economies on the upswing are competing more fiercely for these same resources. Competition for finite natural resources is becoming increasingly high.

Pushing past this global energy competition is a very difficult challenge. A major challenge to bolstering AF energy security is reducing the need for traditional fossil fuels, and the high investment cost of onsite renewable energy sources is still a serious roadblock in this segment. Current levels of technology, however, are making this increasingly more affordable. Onsite renewable energy provides a standalone source of power within the fence line of AF installations.

Another investment hurdle is physical infrastructure security improvements that have no impact on energy consumption. Projects with energy reduction and costs savings are more favorable than projects that provide no economical benefit. Sometimes these projects are needed but remain unfunded indefinitely. Adjusting project funding guidelines to include energy surety along with mission weight will help installations better plan holistically.

This research will take the form of problem/solution framework. With any complex problem, rarely does a single solution exist, so the solutions will be ranked of importance as part of the final recommendation. Taking the problem/solution approach is ideal because this framework allows for logical framing of complex problems and a clear, understandable way of outlining the alternative solutions. As stated in the source section above, this research will take a comprehensive look into energy security with analysis of current energy data, policy and subject matter expert (SME) interviews. The research will have a qualitative emphasis using quantitative

analysis to outline basic energy consumption and production histories and trends. Once the problem factors and potential solutions are considered, the recommendation and conclusion will close out this research, providing a way forward for the AF to improve its energy security measures. Where this research may differ from the typical problem/solution framework guidelines is in the recommendation, which will likely require multiple courses of action to solve fully such a complex problem.

This research paper will first outline some background information regarding energy infrastructure and how the AF manages that infrastructure before exploring historic energy consumption and costs, infrastructure problems, potential risks and future assumptions regarding this field. Then a series of solutions will be discussed along with evaluation criteria for determining the best solution or solutions to the AF's energy security infrastructure problem. Before concluding this research, a complete recommendation will be presented.

Section II – Background

Problem Background and Significance

It is no secret that the Air Force's entire way of life depends on access to energy sources and key to access depends on location and supply levels of these energy sources. Currently, world supply and consumption of fossil fuels is unbalanced. Though the US currently has access to a significant energy supply, its consumption levels are not sustainable forever as more and more countries are developing industrial economies. With China, India, and South America all giving rise to very strong middle classes, global demand for energy will increase.[2] Further, AF installations must have nearly all energy generated and delivered by commercial utility companies.[3] At the installation level, the AF needs a solution to sustaining mission essential operations in the event of a crisis that eliminates energy supply. In the long term, the AF needs a way to consume energy without relying on fossil fuels.

The AF is the largest energy consumer in the Department of Defense (DoD), consuming nearly half of the overall DoD total.[4] Aviation fuel accounts for the vast majority of AF energy consumption, but facility energy still represents a very significant amount. Fossil fuels are a major source of power for the AF, but there is a finite amount of these fuels. Even though new methods of oil and gas extraction have been developed, such as horizontal drilling and hydraulic fracturing, environmental concerns and restrictive state legislatures prohibit the United States from obtaining several fuel reserves within its borders.[5] Further, global competition for these resources makes them increasingly more difficult and expensive to obtain, which is a vulnerability that leaders must consider. Leaders have made attempts to drive the DoD towards renewable energy sources with The Energy Policy Act of 2005, but as of FY2014, the DoD has reached less than half of its renewable source consumption and production goals.[6]

Beyond the problem of sources, our electric power grid is interconnected to provide maximum reach, but much of the infrastructure is exposed. High voltage transmission lines can be seen from the highway and distribution lines are only more recently being installed underground. Even if the AF receives a greater portion of its power from renewable sources, the utility distribution system still highlights a weak point. Utility systems are targets for adversaries because they are vulnerable and damaging them can cause severe impact.

These vulnerabilities are difficult, nearly impossible problems to solve, but by analyzing infrastructure weaknesses, the AF can identify a series of solutions that strengthen physical security, reduce consumption and increase onsite renewable energy generation to improve energy security and help sustain future mission requirements. This research will provide solutions with dispersed, renewable energy sources that can operate in our current interconnected grid, or power AF installations independently in the event of a crisis. As the AF moves into the future, providing reliable, renewable and remote power to an installation under any circumstances is the key to AF energy security.

Utility Acquisition

AF civil engineer (CE) organizations, along with contracting and financial management organizations work with the local utility provider(s) to bring electricity to each installation. Electrical power is transmitted through above ground, utility owned, high voltage power lines before being distributed to individual base facilities through medium voltage distribution system. The transmission lines travel from the utility company's generation point off base to a local transformer that drops the voltage from high to medium voltage. Medium voltage distribution systems can be either overhead or underground and can be either AF owned, utility owned, or a separate privatized system. Where financially feasible, AF installations are privatizing electrical

distribution systems as a way of reducing maintenance and repair burden on both AF labor and budget. Privatization allows the AF to avoid costly repair bills, but transfers payment to the utility line of accounting where these repairs are leveled off and paid incrementally through each bill over several years. Few permanent installations have AF owned, onsite power generation capabilities and those that do use it as supplemental power. Davis-Monthan Air Force Base (AFB) in Arizona and Nellis AFB in Nevada both have operational photovoltaic (PV) solar arrays and Cape Code Air Force Station in Massachusetts has recently completed a wind power project.[7]

From an energy conservation perspective, CE manages the infrastructure piece of the AF-owned electrical systems for any part of the facility that is not directly tied to mission equipment. CE's portion includes lighting, HVAC and convenience power for a facility to operate normally. The operational side of the equation is when a testing or lab mission occupies a facility. These organizations have specific missions that require specialized equipment to operate within the facility in addition to the basic infrastructure. This is considered process energy, not facility energy. CE must maintain and repair the basic infrastructure equipment and can upgrade to more efficient equipment to save on facility energy and money. Any mission or process energy equipment and consumption are the responsibility of the using organization. At each installation, CE is generally charged with meeting federal mandates that require energy consumption reduction though CE does not control energy use across the entire spectrum. When considering energy security, AF installations must consider *both* the source of the energy and how much is consumed.

Section III – Key Issues and Discussion Points

The three key issues and discussion points contained in this section are the Air Force's rising energy costs and consumption, the decaying state of its electrical infrastructure and a series of future assumptions regarding both energy and security. Each of these points has its own set potential risks that accompany it. These points highlight the problem areas that the AF must consider when planning for a more secure energy infrastructure at its installations and will be the focus areas for the solutions section later in this research paper.

Historical Consumption and Costs

Some energy trends can be predicted, others cannot. The AF's facility energy intensity (energy use per square foot) has been reduced in recent years, but will not likely continue to drop. In addition, energy costs will continue to rise a small percentage each year. Analysis can help project each year's energy costs trend in addition to whether or not the agency will meet its consumption goals, but there is a factor that cannot be predicted as easily. Beyond energy goals and costs, ever-changing mission parameters make it difficult to predict what the AF's overall energy requirement will be in the future.

Though the Energy Independence and Security Act of 2007 (EISA 07) and Executive Order (EO) 13692 mandate federal agencies to reduce facility energy intensity, these does not guarantee each agency will meet its goal nor do they achieve the level of energy security needed at AF installations. The AF has reduced its energy intensity over the past decade, but it has not reached its FY14 goal. Further reducing facility energy intensity is constricted by "(1) budget sequestration and delayed appropriations, which lead to a reduction in energy efficiency and conservation projects; (2) uncontrollable variables such as weather and temperature variability…; and (3) a greater reliance on conducting missions at fixed installations and

enduring locations (e.g., training; unmanned aircraft; intelligence, surveillance or reconnaissance missions)."[8] Across the AF the vast majority of low-cost energy conservation projects have already been completed and any further energy intensity reduction will be extremely costly for the AF to execute.

To make this even more challenging, AF missions are flexible and thus, planning for facility requirements is always a moving target. Further, the DoD's infrastructure budget projects a 20% decrease from 2017 to 2020.[9] With almost no budget for constructing new facilities the AF must place any new mission into the footprint of the existing infrastructure. This effectively increases the energy intensity of any given space. As new, expanded missions drive updated technology there is a chance this technology may require more energy to run than what it replaces or it may add to what is already in use. For instance, there always seems to be a need for an increased number of servers in communications facilities, which drives a need for increased electrical supply to those facilities. For this reason, it is not uncommon for installation communications organizations to "outgrow" the facilities they occupy. What facilities and energy infrastructure will be needed to support AF mission in 2050? This becomes extremely difficult to predict the further out one looks.

Energy cost per unit is not likely to trend downward in the future. Electric rates in the United States tend to have an annual peak in the summer and low point in the winter as a result of supply and demand trends, but each year the average annual rate increases from the previous year. From January 2001 to January 2015 industrial and commercial electric rates in the US have increased 41.66% and 40.17%, respectively.[10] These rates did experience a steady state from 2009 and into the start of 2013, but they have again started to rise steadily.

With AF energy intensity reduction starting to stagnate and the AF mission always changing and expanding, it is unlikely that the AF electric demand will shrink in the foreseeable future. Pair this with ever increasing energy costs; the AF electrical energy bill will continue to rise annually. With federal funding constraints still impacting the DoD, this energy bill takes funds away from primary AF missions each year. From an energy surety standpoint, this only works if the AF has the budget for an increased energy bill and the market can provide the energy to the AF.

State of Infrastructure

The AF infrastructure footprint is staggering, and the maintenance and repair costs for this infrastructure is even more so. AF infrastructure that is reaching the end of its life needs to be repaired or replaced, but a shrinking budget delays the needed rehabilitation at many installations. Electrical grids on installations are a mix of overhead and underground distribution lines and are generally fed from a single utility source. Energy backup capability for AF installations is mostly limited to diesel generators for any critical loads, though very few installations do have more robust renewable energy generation capabilities.

Funding electrical grid repairs has no lifecycle payback opportunities like an energy conservation project would have. Infrastructure repair type projects simply fix or replace old material and equipment that has reached its expected lifespan. Further, electrical systems tend to have high material costs that make funding even more challenging. This is work that needs to be done to avoid unnecessary failures, but it is work that does not always score well in Operations and Maintenance (O&M) funding programs. The AF has recognized this and started privatizing utility systems on installations to help alleviate this concern. Utility Privatization (UP) places the ownership of the utility system on an external entities, such as the utility provider company, a

utilities privatization contractor-owner or a local municipality, which then becomes “responsible for construction, operations, maintenance, and repair for the utility production and distribution system from the base fence or real estate boundary to the point of utility delivery to the customer.”[11]

The benefit of this approach is that the UP contractor must make any repairs to the system rather than the AF planning for and executing repairs with infrastructure O&M funding. The UP bill becomes a recurring, relatively level bill for the duration of the contract. Much like a residential utility bill, all the maintenance and repair costs are amortized over time rather than paid for up front. This takes some of the stress off of CE planners who make funding requests each year; those funding requests are far from guaranteed and place the utility infrastructure at a higher risk of failure.

The drawback of a UP approach is that the AF relinquishes a degree of control over its infrastructure to a non-AF agent. This can lead to decreased readiness. Since installation personnel are no longer the maintainers of the system, reaction time to crisis response will be limited. This is not to say that the contractors servicing a privatized system are less capable, it means that there is an added level of administration and potential complication. What contract employees are authorized on base? Are those individuals local? What if the urgent message does not reach the right party? At the very least UP contracts must have a priority clause for the installation when a regional outage occurs, ensuring that adequate human resources are allocated to the mission. Additionally, any changes to the privatized system as a result of new or changed mission must be coordinated and executed through the UP contractor and limit the amount of competition the AF can implement for new projects. This, along with financing maintenance and

repair as part of a UP contract, can potentially cost the AF more money over the life of the system.

The actual electrical grid itself is also a concern, both the type of construction and the approach to an installation's primary feed. Typically, an installation's electrical distribution is fed from one utility provider at one or two points. Even if an installation has a redundant feed from an electricity provider it may be fed from the same circuit or substation. Either way, the single point of failure is simply shifted from one point to another.

The type of installation chosen for the electrical distribution system can also lead to energy security problems. In the past, distribution system design was limited to overhead style systems that are susceptible to severe weather, wind debris or lighting strikes. The normal utility outage cost for the DoD is under $250K each year, but the effects of one severe wind/thunderstorm in 2012 exceeded that cost by 10 times the average.[12] This $2 million cost that the DoD incurred was for maintaining operation of mission critical functions in the absence of commercial utilities.

Further, above ground electrical distribution provide little defense against malicious acts. The applicable tactics an aggressor would likely use against an installations utility infrastructure range from indirect fire weapons to vehicle bombs. The outcome of these tactics used by domestic and international terrorist can be severe.[13] Underground systems have a higher degree of protection because they remain nearly hidden from a potential adversarial threat.

The AF's primary backup capability for critical facilities is diesel generators and the onsite fuel supply requirement is only for 24 hours with a seven day fuel delivery plan.[14] Fuel delivery is required in a serious contingency that impacts commercial power to an installation beyond this amount of time. Depending on the degree of impact and how widespread the disaster/threat is, continuous fuel delivery may also be a problem, especially if an installation has

several dozen critical loads with backup generators.[15] Now the benefit to backup generators is that one is required per critical facility; localized power is generated exactly where needed. They are also extremely reliable when maintained properly. The drawback to this decentralized backup power plan is there are more pieces of equipment to purchase and maintain.

Future Assumptions

To further analyze solutions to these installation energy security issues, a series of educated assumptions based on field research must be made. This research paper assumes that adversaries will continue to seek asymmetrical advantages against the United States, immediate severe weather and long-term climate change will continue globally, finite natural resources remain the primary fuel for the modern world and bottom line AF funding will continue to trend downward. The following analysis of these assumptions helps frame what the optimal solution for installation energy security looks like.

Terrorist organizations and even state-based militaries seek to leverage any advantage they can find over their opponents. US utility networks provide these adversaries a target that if damaged, can impact a wide range of US defenses. Though "no malicious acts (e.g., physical, cyber) were reported as causing utility outages impacting installations in FY 2012, FY 2013, or FY 2014," it does not conclude that they will never happen.[16] Also, it is not a stretch to consider that cyber attacks may shift to more damaging physical attacks on utility networks. Alleged Russian hackers have recently carried out a successful cyber campaign against Ukrainian electrical network, and it is believed that "Russia, Iran and China are all probing the U.S. power grid for vulnerabilities."[17] "DoD's planned funding for military construction between 2016 and 2020 may not be sufficient to prevent the long-term deterioration of its facilities."[18]

Major fiscal and operational costs at AF installations are utility outages caused by severe weather. Acts of nature cause thirty percent of utility outages at DoD installations.[19] The AF cannot assume that weather impacts to missions will remain average. Hurricanes and winter storms can wreak havoc on utility transmission and distribution systems, causing extended duration outages. The AF must understand that its utility systems are at risk from nature and that nature can be extremely unpredictable at times.

Nature does not give humanity a break with weather, but humanity does not seem to be taking a break on nature either. The world runs on fossil fuels and the demand is on the rise. Market supply is artificially dependent on how fast fuels can be extracted from the Earth and at what cost, but the stark reality is that the Earth cannot produce additional resources beyond what exists under its surface. Further, developing nations now use more of these natural resources each year increasing the rate of depletion. This problem is not a short-term problem since the AF will continue to have access to traditional power for a tie. The AF must think long-term to determine how it will operate when access to those traditional power sources is either limited by market factors or restricted by an adversary. At the very least, it is safe to assume market demand for power will cause its costs to rise as discussed in the Historical Costs and Consumption section above.

The US Congress will continue to limit DoD and thus AF funding each year. If funding levels do not meet the overall AF needs, infrastructure funds will decrease even more to allow the AF to maintain mission operations. The 2011 Budget Control Act (BCA) caps the DoD's funding at approximately 11 percent below what is needed through 2021 and "operations funding is usually the first to be curtailed during a budget crunch because such reductions generate immediate savings."[20]

Consider utility outage time, for instance. Globally, the typical utility disruption time at DoD installations is about two and a half days, but a serious equipment failure incident in FY 2014 caused a spike in the overall average to nearly eight days.[21] This new average far exceeds the seven-day backup generator fuel requirement discussed in the previous section. Though some equipment failure is expected, proper maintenance and contingency material supply can reduce the impact when something does fail. With the AF stretching its support funding further each year, it is assumed that proper maintenance levels will become more difficult to achieve, putting the electrical infrastructure at additional risk.

Section IV – Potential Solutions

With an understanding of the installation energy security problems and a likely set of assumptions, a series of potential solutions to the problem are presented. Solution evaluation criteria are also presented along with solutions. An in-depth narrative comparing and contrasting these scores will follow, to include discussion on implementing combinations of multiple solutions to best meet an installations needs.

Evaluation Criteria for Solutions

Evaluation criteria for the proposed solutions will be based on four categories: the cost to implement the solution, the level of technical support to maintain the solution, a short versus long-term outcome, and the degree of threat level mitigated by the solution. Solutions can score points in each of the four categories: zero (0) points for a poor rating, one (1) point for a fair rating and two (2) points for an excellent rating. Summation of the solutions' category points will yield final scores, which will help formulate a final recommendation. Figure 1 shows and example of a solution matrix and if these were the proposed options, Solution #2 would be the best option. Now, this does not mean that there can only be one option. There may be many; each with its own degree of importance or recommended implementation timeframe. Much like planning a military coarse of action, a scoring matrix can aid in determining the best solution (or solutions) for improving infrastructure to maximize installation energy security.

Categories	Solution #1	Solution #2	Solution #3
Cost to Implement	0	2	1
Support Required	2	2	1
Temp/Permanent	1	1	2
Threat Mitigation	2	2	0
TOTAL	5	7	4

Figure 1. Example Solution Matrix

Reduce Consumption

A very common solution to this problem is reducing energy consumption. This is an attractive method because it not only minimizes energy need it reduces energy costs. It can have a positive impact on the environment as well. The Air Force identifies this method as “the single, best action the Air Force can take to improve its energy security. It decreases reliance on foreign energy sources and an aging commercial infrastructure, reduces the financial resources the Air Force needs to commit to energy, and increases the impact on-base renewable sources can have.”[22] This is the AF’s preferred method of energy management because of the limited availability of project funds for infrastructure improvements, though this method has limits based on current technology.

One of the most lucrative energy conservation measures (ECM) is the conversion to light emitting diodes (LED) from older lighting technology. LEDs use a fraction of the power compared to other lighting sources and also have a significantly longer lifespan. The AF has authorized LEDs for exterior applications including taxiway edge lighting for several years, but has only recently approved LED use for interior spaces. UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls* was updated in 2015 authorizes interior LED use and also includes guidelines for lighting control methods, such as daylight harvesting and occupancy sensors, which can really be a savings multiplier. It is important to note that the top two priorities of this UFC are energy *and* maintenance reduction.[23] The AF has plenty of reduction opportunity with lighting.

The most complicated facility ECMs are those related to HVAC systems. Though there are some simple improvements in this area, the general complexity of HVAC systems makes it difficult to predict savings and actually implement the measures. Lifecycle replacement of major

HVAC equipment with more efficient models is a common approach to more expensive systems. Re-commissioning, where the building systems are rebalanced and adjusted for current occupancy can be an effective energy and cost savings method, especially considering how often building tenants increase or change at the installation level. EISA 07 requires energy managers to inspect buildings every four years to determine if re-commissioning is needed.[24] The AF already continuously updates HVAC systems and re-commissions often to keep up with flexible mission requirements at its installations.

Building envelope ECMs, such as new roofs, windows or insulation can reduce energy, but they do not have as great an impact as electrical or mechanical ECMs. Work in this area may lower energy consumption, but it does more for occupant comfort than it does improving energy security. If a roof is not leaking and as long as outside air is not freely entering past a window frame, it is best to leave it be from an energy standpoint.

Process energy is outside of the CE's purview, as it is energy tied directly to a mission related function rather than the facility itself. Energy reduction mandates and goals often fall onto the CE energy management offices at each installation. This can make meeting goals difficult since the responsible agency only manages part of the total energy consumption. Base level partnerships are critical. Other organizations must also consider energy efficiency when specifying new operational equipment.

Rounding out the energy reduction ECM is Airmen culture towards energy. Fostering an energy aware culture is the least expensive, but probably the most difficult ECM to implement. Any attempt at culture change is always difficult. The AF approach to this is to teach Airmen that energy is a mission critical resource with an online training module.[25] The best medium for reaching Airmen is a moving target and the AF must stay abreast of this at all levels, partnering

with Public Affairs where appropriate. Airmen need to better understand the cost burden energy has on the AF and how energy impacts the AF mission.

Infrastructure Upgrade/Alterations

Upgrading physical and cyber infrastructure security is another potential solution to protecting the Air Force's energy supplies. Installation electrical systems are vulnerable to physical attack and severe weather, especially when the systems are installed above ground. On the cyber front, electrical (and other) utility systems are at risk from hackers of any kind, state or non-state. There are opportunities for the AF to improve these vulnerabilities and help shield energy infrastructure from intentional and accidental threats.

Protecting the physical grid on an installation is straightforward. Installing electrical distribution underground, preferably in a concrete encased conduit, will help shield the conductors from severe storms and debris thrown by wind. It also makes it more difficult for adversaries to find parts of the infrastructure. "Distribution lines can fail in numerous ways; bad weather can knock down distribution poles or the circuits can be damaged due to overuse or thermal overloading."[26] AF installations have a combination of underground and overhead distribution systems, depending on the installation and the base standards. Installing overhead lines is more affordable than installing concrete-encased underground system, because the cost of conduit, concrete, insulated conductors, and labor for trenching is much higher than the cost for utility poles. Overhead distribution systems may be more affordable, but at the risk of the system being more vulnerable to severe weather or enemy attack.

In an underground distribution system, only the electrical conductors are installed underground. Transformers, switchgear, panelboards, generators, etc., are all installed at ground level and visible to anyone who knows where to look for this type of equipment. Privacy walls or

fencing can help hide these types of equipment, but unless those walls/fences are secure, any adversary with an understanding of utility systems will quickly identify and attempt to access this equipment. Also, online services such as Google or Bing have clear overhead imagery of many installations. This also makes it difficult to truly mask utility equipment to someone who has an understanding of it. Weather is less of a concern with these types of devices. Electrical equipment installed outside has housings rated for weather and climate that will hold up in most situations; this is not only an AF requirement, but also an industry and code requirement for outdoor electrical equipment.

Outside of the installation fence line is beyond AF control. A utility company will deliver power to an installation using whichever infrastructure system that utility company decides. However, utility companies' security and reliability are strictly monitored by the North American Electric Reliability Corporation (NERC), which is regulated by the Federal Energy Regulatory Commission (FERC). Together, these organizations provide sound practices, including physical security measures for utility companies to provide reliable power to all customers. This does not fully negate the fact that overhead transmission and distribution conductors are exposed.

Microgrids offer a control method for utility systems that allow operators to control power load, energy source, connection with the commercial grid and cyber security measures. A microgrid at a DoD installation "is an integrated energy system consisting of interconnected loads and energy resources which, as an integrated system, can island from the local utility grid and function as a stand-alone system."[27] This upgrade can offer energy security opportunities to existing equipment and systems at AF installations, and it maximizes the use of renewable energy generation that is discussed in the following section.

In addition to managing multiple loads and sources, microgrids offer an additional level of control that installations would not otherwise have. For instance, an incident affecting one part of the grid could cause undue strain on another part that is experiencing a higher power demand. With secure microgrid controls, technicians have the ability to de-energize non-critical loads to maintain continuous critical power without having to start the backup generators. A microgrid also offers benefits to the AF when an incident has no effect on the installation. When requested by FERC, technicians can initiate non-critical load shedding when power plants cannot meet all customer demand. Participating in demand response programs is financially beneficial. If participants reduce demand during the requested response time, the utility company rewards the participants for their efforts. The more a participant reduced demand on the grid, the more money they are paid. Assuming mission critical functions are maintained throughout this time, this is an excellent benefit to implementing a microgrid.

Energy security is not a problem that has risen with the prominence of hackers and non-state actors seeking asymmetrical advantages. There has always been the chance for an installation to lose power and these new threats make that chance even more probable. "Critical loads have historically been required to have a backup energy source to sustain operations if the grid were to go down. This strategy has resulted in installations that have a large number of smaller generators dispersed around the installation typically tied to the low voltage supply for individual buildings. While this system is simple to implement and provides a fairly robust solution to intermittent short duration power outages, it is not a system that is optimized to provide longer duration energy security."[28] The long-term solution to this energy security problem must move beyond the facility backup generator model and implement a robust microgrid in conjunction with diversified sources.

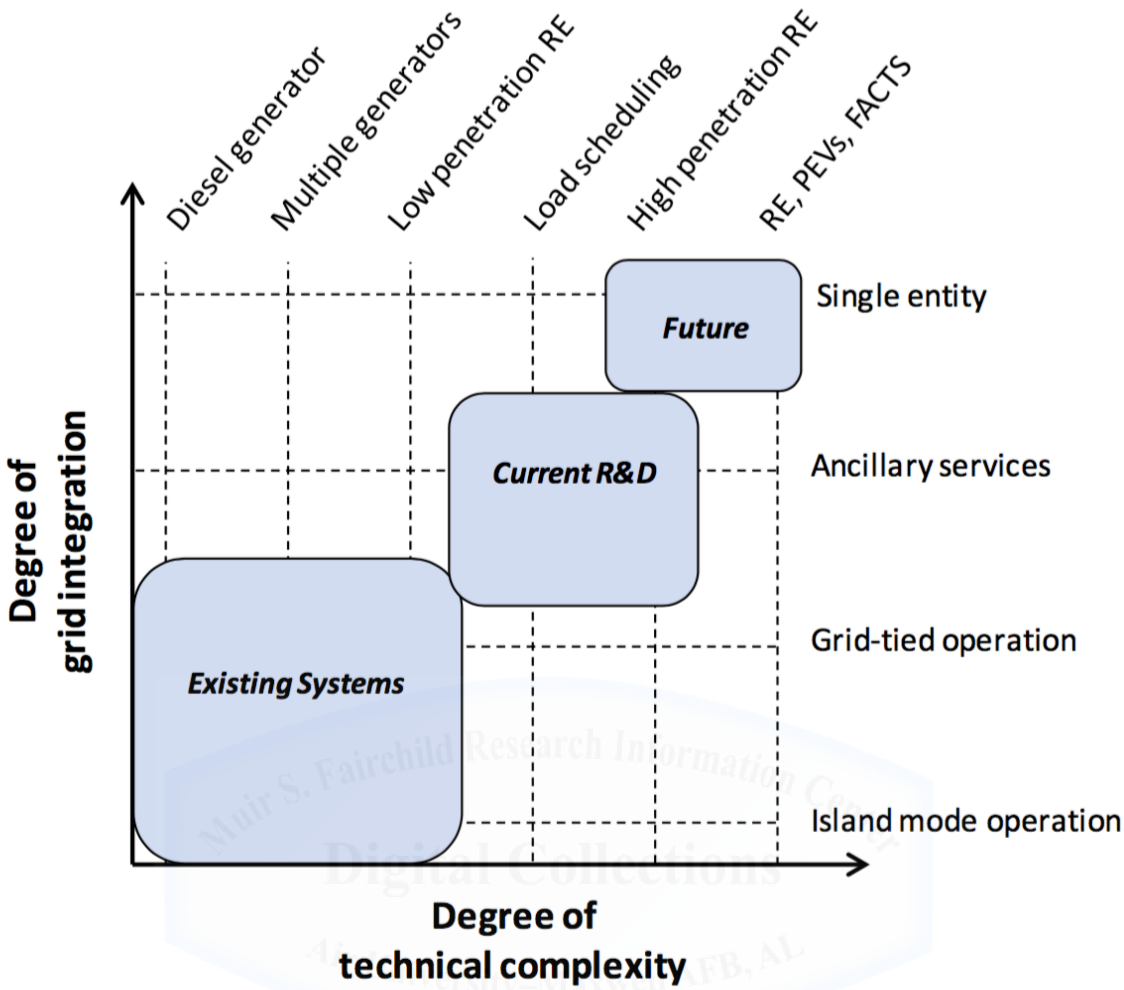

Figure 2. Key Microgrid Parameters[29]

Figure 2 shows the types of microgrids and their respective grid integration and technical complexity. The next section, Alternative Onsite Generation, will discuss what is represented by the "Future" microgrid shown in the top right of Figure 2. Microgrids must be used to properly implement renewable energy generation on AF installations.

Alternative Onsite Generation

Onsite power generation from renewable resources is the pinnacle of energy security. An installation with this capability to meet its critical loads can isolate itself, yet still maintain mission operations for extended periods of time. Onsite renewable power generation also helps

the AF meet federal energy-related mandates, reduce reliance on fossil fuels and make a positive impact on the environment. However, renewables are not without their drawbacks. The amount of renewable generation is site specific, the costs for these systems is rather high and integrating these sources with the commercial grid is also a challenge. Overcoming these challenges will put the AF in position to have assured, secure energy for almost any contingency.

There is no way to completely eliminate energy security concerns. China is a good example. China's energy market is heavily based on importing fuels, more so than the US market. "No strategy, as Beijing and its companies are learning, is infallible. The reality remains that much of the oil and gas that is vital to China's economic growth will continue to be produced in volatile countries, traded on international markets, and flow through the Straits of Malacca."[30] This puts China in a difficult position when trying to fuel its power plants and though the United States has more secured energy sources, it does not mean that it should accept the current strategy alone.

The common methods of renewable energy generation are solar PV, geothermal, wind and biomass, among others. "Geothermal electric power is by far the most significant renewable energy source in DoD, accounting for almost half of the Department's renewable energy goal attainment."[31] Solar, though only producing a quarter as much energy as geothermal, has several hundred more individual projects in the DoD.[32] This is because solar projects output is directly proportional to the costs invested. If an organization has a fixed budget, a small solar array is still an option and that organization can expand the scope of that array in the following years with little effort other than securing the space to install the equipment. Geothermal and biomass both have a very large plant investment cost and are also more difficult to modify for additional capacity. The benefit to geothermal and biomass is they can be implemented almost anywhere,

especially biomass. Solar and wind on the other hand, must be installed where sun and wind are plentiful.

Facility-specific renewable generation and storage are ideal. Much like backup generator, they are local and can "island" themselves from the remainder of the grid if needed. However, until these systems are higher performing and reliable enough not to need extra maintenance, central renewable hubs on base are the best solution to providing backup, renewable power to installations. These renewable energy generation solutions, like all other solutions, require a way to integrate them with the commercial utility grid, which goes back to installation microgrids. The more sources, the more complicated the microgrid.

Contracting Avenues

For any of these solutions to become a reality, the AF must have a method of procuring the materials, labor, and services to accomplish the task. With the federal budget constrained, the AF no longer has dedicated energy focus funds; so all energy projects must compete with all other facility, sustainment, restoration, and modernization (FSRM) projects.[33] Because of this, the AF relies heavily on third-party financing, paying for projects using energy and operational costs savings over the life of the contract.

Energy Savings Performance Contracts (ESPC) and Utility Energy Service Contracts (UESC) are both third-party financing contract avenues. ESPCs are best value competition contracts between a set of energy savings contractors (ESCO) preapproved by the Department of Energy (DoE), and UESCs are sole-source contracts awarded to an installation's serving utility company. Both ESPCs and UESCs have similar milestones.

In either contract type, the contractor proposes a final scope outlining what ECMs should be completed and what the energy savings and costs payback amount to. In this instance, the AF

will immediately feel the energy savings upon project completion, but the cost savings on that reduced energy go towards paying the ESPC or UESC contractor until the project is fully paid. An ESPC payment period can be up to 25 years, but the AF limits UESC payback terms to 10 years. After including the scope development, design, and financing costs with the final installation, these terms *must* be met using the energy cost savings through the payment term.

Third-party financing projects favor quick payback initiatives and therefore are mostly feasible for installations that have a high energy cost rate. This makes it more difficult to execute financed projects at installations that have low energy costs. Some of the highest energy-consuming installations have the lowest energy rates; these installations likely have more of a challenge meeting the payment terms of a UESC or ESPC. Also related to financing these projects is ECM bundling, especially if an installation has very low electrical rates. It is good practice to bundle longer payback ECMs with shorter payback ECMs to achieve higher energy reduction overall, while still keeping a project within strict financing terms. Any installation that has been proactive in executing energy projects in the past will not have the bundle capacity to achieve maximum savings with third-party financing. Funding projects with third-party financing can be successful at some installations, but not all. Funding projects in this manner helps the AF take a small step towards improving energy security, but will not meet the overall goal.

Another difficulty in improving energy security using ESPCs or UESCs is that since they require energy savings, these types of contracts only consider energy conservation and possibly renewable energy projects. Infrastructure or physical security upgrades do not have a cost savings component; they are never included in a UESC or ESPC project scope. This is a problem

because of the Air Force's reliance on these contracting avenues for a significant portion of energy project execution.

Section V – Solution Evaluation and Comparison

The three potential solutions analyzed above are reducing energy consumption, upgrading infrastructure, and constructing alternative onsite power generation. Those three solutions will be evaluated against implementation cost, the support required to maintain, the short- vs. long-term solution, and the level of threat reduced or avoided. After individual evaluation, the solutions will be compared against each other for optimal energy security planning.

Reducing consumption can have some potential energy cost payback depending on the project cost and the amount of energy reduced. The problem the Air Force has with this solution is that many of the cost effective energy reduction projects have been executed in past years. From 2002 to 2014, the AF has reduced its facility energy intensity by 22.3 percent.[34] This reduction represents these simple, high payback projects already completed. Any further reduction requires more complex, costly solutions that may not have the energy cost payback desired. These more complex solutions demand a higher degree of maintenance than past ECMs. Cost and support are both rated at fair.

Reducing the need for energy reduces the AF's reliance on fossil fuels, but unless the reduction is extreme, this alone does not greatly improve energy security. Pairing this solution with renewable power generation, however, is a much stronger solution. Reduction alone does not mitigate a high degree of threat, nor does it make a major change in short- or long-term energy security. Both of these categories are rated poor.

Infrastructure upgrades are expensive and offer no energy cost savings, so it is rated poor for implementation cost. Upgraded infrastructure, such as underground utilities lines, require no additional maintenance than what existing systems require, so this earned an excellent rating.

Upgraded infrastructure is a long-term solution for the section of the system it is protecting, but cannot fully protect the entire system. This solution has a fair rating for the last two categories.

Much like the consumption reduction solution, alternative onsite generation has a portion of energy cost savings, but does not always offset project costs completely. It earns only a fair rating for this category. Renewable generation systems require a significant degree of technical expertise and maintenance. It is possible that AF maintainers will become more technically familiar with these systems, but that still requires the AF to invest in these systems to allow training and exposure. Currently the support required for alternative onsite power generation earns a poor rating. The benefit to onsite renewable generation is that these systems are a long-term solution to providing power to AF installations independent of fossil fuels. In addition, these systems allow installations to "island" themselves from the rest of the grid in a contingency situation, thus allowing the missions to continue under threat to commercial power. These two categories are rated excellent.

Categories	Consumption Reduction	Infrastructure Upgrades/Alterations	Alternative Onsite Generation
Cost to Implement	1	0	1
Support Required	1	2	0
Temp/Permanent	0	1	2
Threat Mitigation	0	1	2
TOTAL	2	4	5

Figure 3. Solution Matrix

Comparing the three proposed solutions, it is clear that alternative onsite generation is the best solution to the Air Force's energy security problem. This is not the only solution, however. Consumption reduction still saves the AF money in the long term and lessens the burden of any onsite generation. For long-term planning, these two solutions should be considered in conjunction with one another, but the emphasis must be on alternative onsite generation.

Infrastructure upgrades are important, but unless there is a reason beyond security, it is not wise to implement these measures without additional resiliency measures. For instance, if a coastal installation has a maintenance and repair problem with overhead power lines as a result of frequent hurricane activity, it makes perfect sense to construct the electrical infrastructure underground. Another installation that does not have this issue may find that it is not valuable to make this upgrade. The utility company's infrastructure may be overhead outside of the installation, so there is not much security benefit to installing the on-base infrastructure underground. Similarly, microgrids are not as beneficial to an installation unless paired with multiple, diversified power sources. This installation upgrade reaches maximum potential when an installation has alternate onsite generation capabilities.

Section VI – Recommendations

The Air Force must focus resources towards increasing alternative onsite energy generation to enable installation missions. Unfortunately federal mandates and project funding rules restrict this from becoming a reality. Too much emphasis is placed on facility projects with energy cost payback and for this reason the Air Force relies too heavily on third-party financed projects. To work towards improving energy security at its installations, the AF must be willing to pay a premium for maintaining assured power for its mission. "As both DoD, and the United States as a whole, address energy challenges, it is generally believed that DoD can use its tradition of innovation and its large buying power to help lead the country toward energy efficiency and toward a sustainable energy future."[35] If the AF does not adopt this mentality, it will stay stagnant on the energy security front.

Renewable energy generation can be completely independent of the facilities being powered and is not tied to the occupants of those facilities. If a facility space changes functions or is renovated, an onsite renewable power generation source can still provide power. Energy conservation projects, however, strictly depend on how the facility space is used. If a building is renovated for a new mission, the lighting systems, HVAC systems, and even windows may need to be changed. Any previously executed energy conservation project on this space is now wasted. The AF spends approximately 98 percent of energy project funding on conservation projects and only one percent on renewable energy projects.[36] Flexibility is key to the AF mission, so facility space rarely stays unchanged for very long at installations. Space is constantly being adjusted to accommodate mission requirements, and therefore, funding is more wisely spent on renewable generation than it is on energy conservation.

Energy conservation must still be considered, but it cannot be the deciding factor in what energy related projects the AF pursues. This means that third-party financing as a primary means to improve energy security will not continue. The AF must use a combination of appropriated funds and energy cost savings to fund energy projects. For instance, completing a UESC or ESPC with a robust onsite renewable energy generation plant may have a payback, but not within the allowable terms of the contract because of the high installation costs or the addition of microgrid capabilities. The AF can pay a portion of contract up front using appropriated funds and finance the remainder for the approved contract term. Alternatively, when a new critical mission is being bed-down at an installation, the AF should consider renewable generation as part of the initial funding to support that critical mission. Energy security cannot be an afterthought, but rather it must be considered as part of the primary mission parameters.

Section VII – Conclusion

The Air Force has an energy security problem. Its installations rely on fossil fuels to feed electrical grids that are exposed to environmental and adversarial threats. The current solution to that problem is geared towards reducing energy consumption to lessen the reliance on fossil fuels and save money spent on operating and maintaining infrastructure. The AF allocates little funding towards these types of projects and instead chooses more risky, third-party financing.

The real solution is to place the weight on assured power for mission operations. This will allow the AF to step away from approving only projects that have an energy cost savings component and consider additional components, such as infrastructure upgrades and alternative onsite power generation in addition to energy conservation projects. It is the culmination of these three solutions, with a strong bias towards onsite renewables that provides the AF with the best opportunity to improve long-term installation energy security.

Endnotes

[1] U.S. Energy Information Administration, "International Energy Statistics," https://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=1/ (accessed 4 January 2016).
[2] Deni, John R., ed., *New Realities: Energy Security in the 2010s and Implications For the U.S. Military* (Strategic Studies Institute and U.S. Army War College Press, 2015), 116.
[3] Department of the Air Force, *U.S. Air Force Energy Strategic Plan, Effective March 2013* (Washington, DC: Secretary of the Air Force, 7.
[4] Ibid., 7.
[5] Deni, 2015, 114-115.
[6] Department of Defense, *Annual Energy Management Report (AEMR), Fiscal Year 2014* (Washington, DC: Assistant Secretary of Defense [Energy, Installations, and Environment]), 9.
[7] Ibid., 42.
[8] Ibid.,19.
[9] Senate Committee on the Budget, *Long-Term Implications of the 2016 Future Years Defense Program*, 114th Cong., 2016, 7.
[10] U.S. Energy Information Administration, "Electricity Data Browser," http://www.eia.gov/electricity/data/browser/#/topic/7?agg=2,0,1&geo=g&freq=M
[11] Air Force Instruction (AFI) 32-1061. *Providing Utilities to U.S. Air Force Installations*, 23 February 2011, 19.
[12] *AEMR*, 2014, 44.
[13] United Facilities Criteria (UFC) 4-020-01. *DoD Security Engineering Facilities Planning Manual*, 11 September 2008, 3-35, 36, 37, 38 & 39.
[14] UFC 3-540-01. *Engine-Driven Generator Systems for Backup Power Applications*, 1 August 2014, 4.
[15] Van Broekhoven, S.B., N. Judson, S.V.T. Nguyen and W.D. Ross, *Microgrid Study: Energy Security for DoD Installations*, Technical Report 1164 (Massachusetts Institute of Technology Lincoln Laboratory, 18 June 2012), 21.
[16] *AEMR*, 2014, 44.
[17] Cory Bennett, "Russia Tied To Cyberattack On Ukrainian Power Grid," *thehill.com*, 5 January 2016, http://thehill.com/policy/cybersecurity/264794-russia-tied-to-cyberattack-on-ukrainian-power-grid.
[18] Senate, 2016, 48.
[19] *AEMR*, 2014, 45.
[20] Senate Committee on the Budget, *Approaches for Scaling Back the Defense Department's Budget Plans*, 113th Cong., 2013, 11 & 29.
[21] *AEMR*, 2014, 45.
[22] *U.S. Air Force Energy Strategic Plan*, 2013, 12.
[23] UFC 3-530-01. *Interior and Exterior Lighting Systems and Controls*, 1 April 2015, 3.
[24] *Energy Independence and Security Act of 2007*, 110th Cong., 1st sess., (4 January 2007), H. R. 6-118.
[25] *U.S. Air Force Energy Strategic Plan*, 2013, 16.
[26] Schill, David, *Improving Energy Security for Air Force Installations*, (Santa Monica, CA: RAND, September 2015), 102.
[27] Van Broekhoven, et al., 2012, 3.

[28] Ibid., 20.
[29] Ibid., 39.
[30] Deni, 2015, 198.
[31] *AEMR*, 2014, 38.
[32] Ibid., 39.
[33] Ibid., 25.
[34] *AEMR*, 2014, 21.
[35] Deni, 2015, 352.
[36] *AEMR*, 2014, 66.

Bibliography

Air Force Instruction (AFI) 32-1061. *Providing Utilities to U.S. Air Force Installations*, 23 February 2011.

Anderson, William C., Esq,. M.SAME, "In Pursuit of Energy Surety," *The Military Engineer* 106, no. 689 (May-June 2014).

Bennett, Cory, "Russia Tied To Cyberattack On Ukrainian Power Grid," *thehill.com*, 5 January 2016, http://thehill.com/policy/cybersecurity/264794-russia-tied-to-cyberattack-on-ukrainian-power-grid.

Deni, John R., ed., *New Realities: Energy Security in the 2010s and Implications For the U.S. Military* (Strategic Studies Institute and U.S. Army War College Press, 2015).

Department of Defense, Annual Energy Management Report (AEMR), Fiscal Year 2014 (Washington, DC: Assistant Secretary of Defense [Energy, Installations, and Environment]).

Department of the Air Force, U.S. Air Force Energy Strategic Plan, Effective March 2013 (Washington, DC: Secretary of the Air Force.

Energy Independence and Security Act of 2007, 110th Cong., 1st sess., (4 January 2007).

Executive Order (EO) 13693, Planning for Federal Sustainability in the Next Decade, 19 March 2015.

Farrell, Alexander E., Hisham Zerriffi, Hadi Dowlatabadi. "Energy Infrastructure and Security." *Annual Review of Environment and Resources* 29, (2004): 421-469. http://search.proquest.com.aufric.idm.oclc.org/docview/219848973?accountid=4332*y* (accessed 4 January 2016).

Pumphrey, Carolyn W., ed., *The Energy and Security Nexus: A Strategic Dilemma* (Strategic Studies Institute and U.S. Army War College Press, 2012).

Schill, David, *Improving Energy Security for Air Force Installations*, (Santa Monica, CA: RAND, September 2015).

Senate Committee on the Budget, *Long-Term Implications of the 2016 Future Years Defense Program*, 114th Cong., 2016.

Senate Committee on the Budget, *Approaches for Scaling Back the Defense Department's Budget Plans*, 113th Cong., 2013.

U.S. Energy Information Administration, "International Energy Statistics," https://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=1/ (accessed 4 January 2016).

U.S. Energy Information Administration, “Electricity Data Browser,” http://www.eia.gov/electricity/data/browser/#/topic/7?agg=2,0,1&geo=g&freq=M

United Facilities Criteria (UFC) 3-440-01. *Facility-Scale Renewable Energy Systems*, 1 July 2015.

United Facilities Criteria (UFC) 3-530-01. *Interior and Exterior Lighting Systems and Controls*, 1 April 2015.

United Facilities Criteria (UFC) 3-540-01. *Engine-Driven Generator Systems for Backup Power Applications*, 1 August 2014.

United Facilities Criteria (UFC) 4-020-01. *DoD Security Engineering Facilities Planning Manual*, 11 September 2008

Van Broekhoven, S.B., N. Judson, S.V.T. Nguyen and W.D. Ross, *Microgrid Study: Energy Security for DoD Installations*, Technical Report 1164 (Massachusetts Institute of Technology Lincoln Laboratory, 18 June 2012).